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METHODS AND APPARATUS FOR MEDIA LEVEL MEASUREMENT

JOINT INVENTORS:

Gerard J. Carlson

David E. Smith

and

Douglas M. Guillory

METHODS AND APPARATUS FOR MEDIA LEVEL MEASUREMENT

BACKGROUND

Various kinds of imaging apparatuses that form images on sheet media using corresponding imaging media are known. Examples of such imaging media include liquid media or "ink" (in the case of an inkjet printer), dry media or "toner" (in the case of a laser printer), etc. Typically, an imaging media is supported within a reservoir – often in the form of a disposable cartridge – and is progressively consumed during the course of imaging operations. As such, the supply of imaging media within a corresponding imaging apparatus must eventually be replenished (i.e., cartridge replacement, etc.).

As the quantity of imaging media within a reservoir approaches some relatively low level, the quality of the images formed on sheet media by the imaging apparatus can become generally unsatisfactory. Typical examples of such unsatisfactory quality include streaks on the imaged sheet media, voids in the formed image content, etc. Generally, the only solution to these and similar problems is the replenishment of the imaging media within the imaging apparatus.

Because many kinds of imaging apparatus use disposable (or recyclable) cartridge reservoirs to provide the imaging media used therewith, it is typically necessary to have on hand (or timely access to) a new, generally full cartridge reservoir or a bulk supply of imaging media in order to replenish the imaging media with as little inoperative time (i.e., "downtime") of the imaging apparatus as possible. On the other hand, it is generally undesirable to maintain an excessive supply of replacement imaging media or associated cartridges due to the corresponding costs, required storage space, etc.

Therefore, it is desirable to provide methods and apparatus that address the problems described above.

SUMMARY

One embodiment of the present invention provides for a media level measurement apparatus, the apparatus including a sensor configured to provide a temperature signal corresponding to the ambient temperature, and a controller configured to provide a first signal and a second signal. The apparatus also includes a source configured to provide a pulse of electrical current in response to the first signal. Also, the apparatus includes a thermistor device that is electrically coupled to the source and configured to provide a level signal corresponding to a level of a media in contact with a lengthwise portion of the thermistor device during the pulse of electrical current.

1 The apparatus further includes a signal processor. The signal processor is configured to
2 provide a media level signal in accordance with a comparison between the level signal
3 and the temperature signal in response to the second signal.

4 Another embodiment of the present invention provides for a level measurement
5 apparatus, the apparatus including a microcontroller. The microcontroller includes an
6 executable program code and a plurality of lookup tables, each of the lookup tables
7 including level data. The program code is configured to cause the microcontroller to
8 provide a trigger signal, to sense a level signal at a predetermined time after providing
9 the trigger signal, and to sense an ambient temperature signal. The program code is
10 further configured to cause the processor to cross-reference a particular one of the
11 plurality of lookup tables in correspondence to the ambient temperature signal, to cross-
12 reference particular level data within the particular lookup table corresponding to the
13 level signal, and to provide an imaging media level signal in accordance with the
14 particular data.

15 Yet another embodiment of the present invention provides for an imaging
16 apparatus, the apparatus configured to form images on a sheet media. The imaging
17 apparatus includes a reservoir configured to support an imaging media, the reservoir
18 defining a depth-wise dimension. The imaging apparatus also includes a thermistor
19 device configured to provide a level signal corresponding to a quantity of an imaging
20 media within a majority of the depth-wise dimension of the reservoir. Also, the imaging
21 apparatus includes a controller coupled in signal communication with the thermistor
22 device. The controller is configured to control at least one operation of the imaging
23 apparatus in accordance with the level signal.

24 Still another embodiment of the present invention provides a method of
25 measuring a media level. The method includes providing a thermistor device, supporting
26 a lengthwise portion of the thermistor device in contact with the media, and applying an
27 electrical pulse to the thermistor device. The method also includes waiting for a
28 predetermined period of time, sensing a level signal from the thermistor device after the
29 predetermined period of time, and sensing an ambient temperature. The method further
30 includes comparing the ambient temperature to the level signal, and providing a media
31 level signal in response thereto.

32 These and other aspects and embodiments will now be described in detail with
33 reference to the accompanying drawings, wherein:

DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram depicting an imaging system in accordance with one embodiment of the present invention.

Fig. 2 is a signal timing diagram of the imaging system of Fig. 1.

Fig. 3 is a block diagram depicting sensor circuitry in accordance with another embodiment of the present invention.

Fig. 4 is block diagram depicting a plurality of lookup tables of the sensor circuitry of Fig. 3.

Fig. 5 is a block diagram depicting sensor circuitry in accordance with yet another embodiment of the present invention.

Fig. 6 is a front elevation view depicting a thermistor level sensor in accordance with still another embodiment of the present invention.

Fig. 6A is front elevation view depicting a thermistor level sensor in accordance with another embodiment of the present invention.

Fig. 6B is a front elevation view depicting a thermistor level sensor in accordance with yet another embodiment of the present invention.

Fig. 6C is a front elevation view depicting a thermistor level sensor in accordance with another embodiment of the present invention.

Fig. 7 is a side elevation schematic depicting a thermistor level sensor in accordance with still another embodiment of the present invention.

Fig. 8 is side elevation view depicting a thermistor level sensor in accordance with another embodiment of the present invention.

Fig. 8A is a side elevation view depicting a thermistor level sensor in accordance with yet another embodiment of the present invention.

Fig. 9 is a front elevation view depicting a thermistor level sensor in accordance with still another embodiment of the present invention.

Fig. 10 is a side elevation sectional view depicting a thermistor level sensor in accordance with another embodiment of the present invention.

Fig. 11 is a side elevation sectional view depicting a thermistor level sensor in accordance with yet another embodiment of the present invention.

Fig. 12 is a flowchart depicting a method in accordance with another embodiment of the present invention.

DETAILED DESCRIPTION

In representative embodiments, the present teachings provide methods and apparatus for measuring a level or quantity of imaging media within the reservoir of an imaging apparatus. Various embodiments of level sensors that use respective thermistor configurations are provided, with each generally referred to herein as a thermistor level sensor. Each thermistor level sensor defines at least one lengthwise portion that is in contact with the imaging media being measured. Also, suitable embodiments of sensor circuitry are provided that are configured to provide a controlled pulse of electrical current to a corresponding thermistor level sensor during typical measurement operation.

Upon the application of the pulse of electrical current, the thermistor level sensor begins to self-heat, warming to a temperature generally greater than ambient, but generally limited to a temperature less than that at which the measured imaging media would be altered, degraded, or otherwise heat damaged. A portion of the heat energy generated by the thermistor level sensor is then transferred to the contacting imaging media, resulting in an eventual steady-state thermal condition (i.e., temperature) of the thermistor level sensor in accordance with the level or quantity of imaging media in contact therewith.

The sensor circuitry generally, but not necessarily, waits until this steady-state condition is reached and then samples the voltage across the thermistor level sensor for use in deriving a media level signal corresponding to the level (quantity) of imaging media within the reservoir. This media level signal can then be used, for example, to control an imaging apparatus, to provide a user message or alert indicating that media level is low, etc.

Turning now to Fig. 1, a block diagram depicts an imaging system 100 in accordance with one embodiment of the present invention. The imaging system 100 includes an imaging apparatus 102. The imaging apparatus 102 includes a controller 104. The controller 104 is configured to control a number of typical operations of the imaging apparatus 102. As such, the controller 104 can be defined by any electronic controller thus configured. The controller 104 can include, for example: a microprocessor or microcontroller; a state machine; analog, digital and/or hybrid electronic circuitry; electronic memory; input/output circuitry; etc. (not shown, respectively). One of skill in the imaging control arts can appreciate that any number of suitable such controllers 104 can be provided as required and/or desired, and that further elaboration is not required for an understanding of the present invention.

1 The imaging apparatus 102 also includes an imaging engine 106 coupled in
2 controlled relationship with the controller 104. The imaging engine 106 is generally
3 configured to form images on sheet media (not shown) under the corresponding signal
4 control of the controller 104. Non-limiting examples of the imaging engine 106 include
5 an inkjet imaging engine, a laser imaging engine, etc. Other types of imaging engine
6 106 can also be used. In any case, the imaging engine 106 forms images through the
7 controlled application of a suitable imaging media 108 (described hereafter) to sheet
8 media (not shown).

9 The imaging apparatus 102 also includes an imaging media reservoir (hereafter,
10 reservoir) 110. The reservoir 110 is generally configured to support a quantity of
11 imaging media 108 (introduced above) in deliverable communication with the imaging
12 engine 106. In one embodiment, the reservoir 110 is configured to generally define a
13 selectively installable and removable (i.e., disposable or recyclable) cartridge. In
14 another embodiment, the reservoir 110 generally defines a permanent, refillable fixture
15 within the imaging apparatus 102. Other embodiments (not shown) of the reservoir 110
16 can also be used.

17 In any case, the reservoir 110 generally defines a depth-wise dimension "D" such
18 that the imaging media 108 is considered to occupy a level "L" within the depth-wise
19 dimension D of the reservoir 110. As the imaging media 108 is consumed during the
20 course of normal operation of the imaging apparatus 102 (described in detail hereafter),
21 the level L of the imaging media 108 within the reservoir 110 drops correspondingly.

22 The imaging apparatus 102 further includes a sensor circuitry 112 and a
23 thermistor level sensor (hereafter, "TLS") 114. The sensor circuitry 112 is coupled in
24 signal communication with the controller 104, and is electrically coupled to the TLS 114.
25 The sensor circuitry 112 can include any suitable such circuitry in accordance with the
26 present invention.

27 The TLS 114 is typically supported within the reservoir 110 such that a
28 lengthwise portion of the TLS 114 is in contact with the level L of the imaging media 108.
29 The TLS 114 is generally configured to provide an electrical resistance that is measured
30 (i.e., sensed, or detected) as a corresponding voltage drop in accordance with the level
31 L of the imaging media 108 that is in contact with the lengthwise portion of the TLS 114,
32 in response to an applied pulse of electrical current provided by the sensor circuitry 112.
33 In this way the TLS 114 is configured to provide a signal corresponding to the level or
34 quantity of imaging media 108 present within the reservoir 110. Further elaboration of

1 the TLS 114 and the corresponding level signal is provided hereafter in regard to the
2 typical operation of the imaging system 100.

3 The imaging system 100 can further include a user computer 116. The user
4 computer 116 can be coupled in signal and data communication with the controller 104
5 of the imaging apparatus 102. The user computer 116 can include any suitable such
6 computer generally configured to selectively generate and/or provide an electronic
7 document file (not shown) to the imaging apparatus 102 for imaging on sheet media (not
8 shown). Furthermore, the user computer 116 is typically configured to receive various
9 status signals or messages from the controller 104 regarding the state or conditions
10 within the imaging apparatus 102 including, in some embodiments, messages
11 corresponding to the level L of the imaging media 108 within the reservoir 110.

12 Fig. 2 is a signal timing diagram 200 in accordance with the imaging system 100
13 of Fig. 1. Reference is now made to Figs. 1 and 2 as described hereafter.

14 Typical exemplary operation of the imaging system 100 (Fig. 1) is as follows: the
15 user computer 116 communicates an electronic document file (i.e., print job) to the
16 controller 104 of the imaging apparatus 102. The controller 104 then requests that the
17 sensor circuitry 112 - in cooperation with the TLS 114 - provide a media level signal
18 corresponding to the quantity of imaging media 108 within the reservoir 110.

19 In response to this request, the sensor circuitry 112 (Fig. 1) electrically energizes
20 the TLS 114 using a predefined pulse of electrical current 202 (Fig. 2). The TLS 114
21 (Fig. 1) begins to self-heat in response to the applied electrical pulse 202 (Fig. 2). A
22 portion of this heat energy is thermally transferred to that quantity (i.e., level L) of the
23 imaging media 108 (Fig. 1) that is in contact with the lengthwise portion of the TLS 114.
24 In turn, the TLS 114 provides an electrical resistance corresponding to the degree
25 (magnitude) of self-heating that occurs as a function of the level L of imaging media 108
26 in contact therewith.

27 Typically, the TLS 114 (Fig. 1) defines a positive temperature coefficient such
28 that a greater level L of imaging media 108 in contact with the TLS 114 corresponds to a
29 lesser degree of self heating of the TLS 114, in turn resulting in a lesser electrical
30 resistance of the TLS 114. This electrical resistance of the TLS 114 is detected as a
31 directly proportional voltage 204 (Fig. 2) across the TLS 114 (Fig. 1) by the sensor
32 circuitry 112. The voltage 204 (Fig. 2) across the TLS 114 (Fig. 1) is generally referred
33 to herein as a level signal. To clarify, a decreasing level L of the imaging media 108
34 typically corresponds to an increasing level signal provided by (i.e., voltage 204 across)
35 the TLS 114.

1 The sensor circuitry 112 (Fig. 1) then waits until a latter portion of the applied
2 electrical pulse 202 (Fig. 2) and then senses the level signal 204 at a value 208 provided
3 by the TLS 114 (Fig. 1). As depicted in Fig. 2, this sensing, or volt sampling, occurs
4 during (i.e., in response to) the assertion of a sampling signal 206 provided by the
5 sensing circuitry 112 (Fig. 1). In this way, the level signal 204 (Fig. 2) provided by the
6 TLS 114 (Fig. 1) is sampled at or before a substantially steady-state value 208 (Fig. 2) in
7 accordance with the nature of the self-heating of the TLS 114 (Fig. 1), the transfer of
8 energy to the imaging media 108, the ambient temperature, and other related factors.

9 After sensing the level signal 204 (Fig. 2) of the TLS 114 (Fig. 1), the sensor
10 circuitry 112 then compares the value 208 (Fig. 2) with the ambient temperature
11 adjacent or within the reservoir 110 (Fig. 1), as sensed by a discrete temperature sensor
12 (not shown). The precise nature of the comparison varies from one embodiment of the
13 sensor circuitry 112. In another embodiment, for example, the sensor circuitry 112 uses
14 the level signal directly without comparison to an ambient temperature. A number of
15 various such embodiments and their methods of comparison in accordance with the
16 present invention are described in detail hereafter.

17 In any event, the sensor circuitry 112 (Fig. 1) then provides a media level signal
18 (i.e., measurement) to the controller 104. For purposes of example, it is assumed that
19 the media level signal indicates a quantity of media 108 suitable to begin imaging the
20 print job. Next, the controller 104 causes the imaging engine 106 to form images on
21 sheet media (not shown), one sheet at a time, in accordance with the content of the print
22 job.

23 While the imaging operation is in progress, the level of the imaging media 108
24 (Fig. 1) within the reservoir 110 drops (i.e., decreases) in correspondence to the
25 consumption of the imaging media 108 by the imaging engine 106. Also during the
26 imaging operation, the controller 104 is assumed to poll the sensor circuitry 112 to
27 provide a sequence of updated media level signals corresponding to the instantaneous
28 quantity of the imaging media 108 within the reservoir 110.

29 For ongoing purposes of example, it is further assumed that at some point in the
30 present print job the level L of the imaging media 108 drops to a predefined, relatively
31 low level within the reservoir 110. The sensor circuitry 112 detects this occurrence by
32 way of the TLS 114, and provides a media level signal to the controller 104 in
33 accordance therewith. The controller 104 then alerts a user to the low level L of imaging
34 media 108 by way of a suitable message communicated to the user computer 116.
35 Such a message can include, for example, a measurement of the remaining imaging

1 media 108 in terms of percentage full, an estimate of the number of sheets still
2 imageable therewith, etc.

3 The pending print job is now completed, with a user of the user computer 116 put
4 on notice that the imaging media 108 within the imaging apparatus 102 will require
5 replenishment so as to continue any appreciable amount of use. Once again referring to
6 Fig. 2, the electrical pulse 202 and the sampling signal 206 are referred to as first and
7 second signals, respectively, for purposes herein.

8 Thus, the imaging system 100 is usable to form images on sheet media, while
9 also tracking the level L of imaging media 108 within the reservoir 110. In this way, the
10 controller 104 of the imaging system 100 can use the media level signal provided by the
11 sensor circuitry 112 and the TLS 114 for a variety of purposes such as, for example:
12 automatically halting sheet media imaging in the event that the sensed level L of the
13 imaging media 108 is likely to result in undesirable image quality (e.g., streaks, voids,
14 etc.); to alert a user to generally low level of the imaging media 108; to simply provide a
15 level measurement message to a user of the user computer 116 in response to a user
16 request for such a measurement; predict a future outage of imaging media 108; to
17 provide a prediction of the number of sheet media pages still satisfactorily image-able by
18 the remaining imaging media 108; etc.

19 Other suitable uses for the media level signal provided by the sensor circuitry
20 112, in conjunction with the TLS 114, can also be provided. In any case, the TLS 114
21 and the sensor circuitry 112 of the present invention substantially resolve the problems
22 described above, in regard to the undesirable imaging quality resulting from a relatively
23 low level of imaging media within an imaging apparatus, while simultaneously providing
24 the option to predict a need to replenish the imaging media supply (i.e., replace a
25 cartridge reservoir). In this way, the instant invention generally eliminates undesirable
26 imaging results and imaging apparatus downtime due to lack of imaging media, while
27 substantially preventing the need to keep excessive imaging media on hand.

28 In the typical exemplary operation of the imaging system 100 described above,
29 the quantity of the imaging media 108 is generally detected during heating of the TLS
30 114. However, it is to be understood that in another embodiment (not shown), the
31 quantity of the imaging media 108 can be generally determined during cooling of the
32 TLS 114 (i.e., after the electrical pulse 202 is terminated) from its electrically heated
33 condition back toward ambient temperature. In such an embodiment (not shown), the
34 rate at which the electrical resistance of the TLS 114 changes during cooling is
35 substantially indicative of the level L of the imaging media 108 within the reservoir 110,

1 and is detected by the associated sensor circuitry 112 for use in providing a
2 corresponding media level signal to the controller 104.

3 Fig. 3 is a block diagram depicting a sensor circuitry 312 in accordance with
4 another embodiment of the present invention. The sensor circuitry 312 includes a
5 microcontroller 320. The microcontroller 320 includes a signal processor 322. The
6 signal processor 322 can be defined by any suitable processor configured to control
7 normal operations of the sensor circuitry 312 consistent with the present invention, and
8 in accordance with an executable program code 324 (described in detail hereafter). As
9 such, one of skill in the embedded control arts can appreciate that a number of different
10 suitable microcontrollers 320 can be used.

11 The signal processor 322 includes an analog-to-digital (hereafter, A-D) converter
12 326. The A-D converter 326 is generally configured to convert analog signals (i.e.,
13 voltage signals continuous over a range) to a suitable binary-bit format for use by the
14 signal processor 322. Typically, the A-D converter 326 is a standard element of the
15 microcontroller 320 and is therefore inherently compatible with the signal processor 322.

16 The microcontroller 320 also includes a pulse control 328. The pulse control 328
17 is coupled in controlled relationship with the signal processor 322 and is generally
18 configured to selectively control a current source 330 (described in detail hereafter) in
19 accordance with control signals provided by the signal processor 322. In one
20 embodiment (not shown) the pulse control 328 is considered to be a portion of the signal
21 processor 322. Other embodiments of the pulse control 328 can also be used. In any
22 case, the pulse control 328 includes any suitable electronic circuitry necessary for
23 controlling the current source 330. Non-limiting examples of such pulse control 328
24 circuitry include transistor switches, switching diodes, timing electronics, analog and/or
25 digital circuitry, etc. For purposes herein, the pulse control 328 can be generally
26 considered to serve as an interface device between the signal processor 322 and the
27 current source 330.

28 The sensor circuitry 312 further includes the current source 330 introduced
29 above. The current source 330 is coupled in controlled relationship with the signal
30 processor 322 by way of the pulse control 328. The current source 330 is configured to
31 selectively provide a pulse of electrical current to an electrically coupled thermistor level
32 sensor (hereafter, TLS) 314 in response to a pulse control signal provided of the pulse
33 control 328. It is to be understood that the TLS 314 is generally equivalent to the TLS
34 114 described above in regard to the imaging system 100 of Fig. 1 – that is, the TLS 314

1 can be generally defined by any suitable thermistor level sensor in accordance with the
2 present invention.

3 The microcontroller 320 of the sensor circuitry 312 further includes a
4 computer-accessible storage device (hereafter, memory) 332. The memory 332 is
5 coupled in data communication with the signal processor 322, and is typically an
6 inherent element of the microcontroller 320. The memory 332 is accessible by the
7 signal processor 322 for purposes of selectively storing and retrieving various kinds of
8 data therein. The memory 332 includes the executable program code (hereafter,
9 program code) 324 introduced above. The program code 324 is configured to cause the
10 signal processor 322 to control various normal operations of the sensor circuitry 312 in
11 accordance with the present invention. Typical such operations are described in detail
12 hereafter.

13 The memory 332 can include a plurality of lookup tables 340. Each of the lookup
14 tables 340 can be selectively accessible by the signal processor 322, and can include
15 media level data corresponding to level signals provided by the TLS 314. The lookup
16 tables 340 are described in further detail hereafter in regard to Fig. 4.

17 The sensor circuitry 312 as depicted also includes an ambient temperature
18 sensor (hereafter, ATS) 334 coupled in signal communication with the signal processor
19 322. The ATS 334 is generally configured to provide a temperature signal
20 corresponding to the ambient temperature in the relative near vicinity of the TLS 314.
21 The ATS 334 can be defined by any suitable temperature sensor. In one embodiment,
22 the ATS 334 and the TLS 314 are selected such that both have substantially equivalent
23 temperature coefficients (i.e., voltage or electrical resistance versus temperature
24 responses). Other embodiment of ATS 334 can also be used.

25 Fig. 4 is a block diagram depicting the plurality of lookup tables 340 introduced
26 above in regard to the sensor circuitry 312 of Fig. 3. Each of the plurality of lookup
27 tables 340 is typified by the exemplary lookup table 342. The exemplary lookup table
28 342 includes a number of data rows, or records, 344. Each data record 344 includes a
29 range of signal voltage data 346 and a corresponding quantity or level data 348. The
30 signal voltage data 346 represents a voltage signal provided by the TLS 314 (Fig. 3),
31 while the level data 348 represents the quantity or "percent full" of a reservoir of imaging
32 media (such as the reservoir 110 of Fig. 1) being measured by the associated TLS 314.

33 Furthermore, each of the lookup tables 340 corresponds to a range of ambient
34 temperatures as sensed by the ATS 334 of Fig. 3. In this way, a lookup table 340 is
35 selected in accordance with a temperature signal provided by the ATS 334, and

1 thereafter a particular record 344 is selected within the selected lookup table 340 in
2 accordance with the level signal data provided by the TLS 314.

3 It is to be understood the other embodiments of the lookup tables 340
4 corresponding to other embodiments of the sensor circuitry 312 of Fig. 3 can also be
5 used. For example, other data related to an estimated number of "imaged sheets
6 remaining" can also be included. Other useful data can, of course, be included within
7 the lookup tables 340 as desired.

8 Reference is now made to Figs. 3 and 4 as directed hereafter. Typical operation
9 of the sensor circuitry 312 (Fig. 3) is as follows: to begin, it is assumed that the TLS 314
10 is in lengthwise contact with an imaging media of an imaging apparatus (not shown; see
11 the reservoir 110 of imaging media 108 of Fig 1) and that the signal processor 322
12 receives a request for a media level signal or measurement (e.g., the controller 104 of
13 Fig. 1).

14 In response to the request, the signal processor 322, under the control of the
15 program code 324, signals the current source 330 – by way of the pulse control 328 - to
16 provide a substantially constant-magnitude flow of electrical current to the TLS 314, thus
17 defining the beginning of an electrical pulse. For purposes herein, this signaling of the
18 current source 330 by the signal processor 322 is considered a first signal. The signal
19 processor 322 then waits for a predefined period of time during a first portion of the
20 electrical pulse applied to the TLS 314.

21 The TLS 314 (Fig. 3) self-heats in response to the applied electrical pulse from
22 the current source 330, and transfers some portion of this heat energy to imaging media
23 in contact with the TLS 314. As a result, a general rise in voltage occurs across the TLS
24 314 as depicted in Fig. 3 as nodes "A" and "B". This voltage signal, or level signal,
25 eventually reaches a generally constant, steady-state value in accordance with the level
26 of imaging media (e.g., imaging media 108) in contact with the TLS 314. The level
27 signal is electrically coupled to the signal processor 322 by way of suitable coupling
28 therewith.

29 At this time, during a predefined later portion of the electrical pulse provided by
30 the current source 330 (Fig 3), the signal processor 322 causes the A-D converter 326 to
31 sample the level signal at nodes A and B, and to provide a digital equivalent (i.e.,
32 "digitization") of the detected level signal. For purpose herein, this signaling of the A-D
33 converter 326 is considered a second signal.

34 Once the level signal is sampled and "digitized", the signal processor instructs the
35 A-D converter 326 (Fig. 3) to sample and digitize the ambient temperature signal as

1 provided by the ATS 334. Thereafter, the signal processor 322 accesses the plurality of
2 lookup tables 340 within the memory 332. The signal processor 322 then uses the
3 ambient temperature signal to select one of the lookup tables 340 (Fig. 4), and thereafter
4 selects a record 344 within the selected lookup table 340.

5 For purposes of example, it is assumed that the ambient temperature was such
6 that the exemplary lookup table 342 (Fig. 4) was selected, and that the level signal as
7 provided by the TLS 314 (Fig. 3) was equal to 1.07 volts. The signal processor 322 (Fig.
8 3) then selects a record 350 (Fig. 4) within the exemplary 342, as the level signal of 1.07
9 volts is within the range of the signal voltage data 346 for the record 350. By cross
10 reference within the record 350, the signal processor 322 (Fig. 3) reads the associated
11 level data 348 (Fig. 4) within the record 350. From this data 348, the signal processor
12 322 (Fig. 3) determines that the reservoir sensed by the TLS 314 is approximately 3%
13 full of imaging media.

14 As such, the signal processor 322 (Fig. 3) then provides a corresponding signal,
15 or message, to the requesting controller (i.e., the controller 104) indicative of the
16 determined (i.e., sensed, or measured) 3%-of-full quantity of imaging media.

17 At a predefined, relatively short time after the first signal, the signal processor
18 322 (Fig. 3) causes the current source 330 to halt the present application of electrical
19 current to the TLS 314, thus ending the present electrical pulse. In response, the TLS
20 314 is assumed to begin cooling towards ambient temperature. A signal measurement
21 operation (iteration) of the sensor circuitry 312 and associated TLS 314 is now
22 considered complete.

23 Thus, the sensor circuitry 312 and the TLS 314 of Fig. 3 generally provide for the
24 measurement of the present quantity of an imaging media (e.g., imaging media 108 of
25 Fig. 1) within an imaging apparatus and a level signal (i.e., message) corresponding
26 thereto. As depicted in Fig. 3, a relative bulk of the functions performed by the sensor
27 circuitry 312 are provided by way of the microcontroller 320 in conjunction with the
28 program code 324. It is to be understood that other embodiments of the sensor circuitry
29 312 (not shown) can also be provided that do not include the microcontroller 320.

30 Under such an embodiment (not shown) of sensor circuitry 312, the signal
31 processor 322, the A-D converter 326, the memory 332 (and the associated program
32 code 324 and lookup tables 340), and the pulse control 328 are respectively defined by
33 suitable electronic circuits and/or devices. In such an embodiment, the pulse control 328
34 can include timing circuitry used to coordinate the normal operations of the sensor
35 circuitry 312 – thus, the pulse control 328 can be generally considered to function as a

1 master controller. Other embodiments (not shown) of the sensor circuitry 312 that are
2 generally consistent with normal operations described above in regard to the sensor
3 circuitry 312 of Fig. 3 can also be used.

4 In yet another embodiment (not shown) of the present invention, sensor circuitry
5 312 can be provided that compares the level signal from the TLS 314 with the
6 temperature signal provided by the ATS 334, and thereafter provides a media level
7 signal in accordance with a comparison (such as, for example, by subtracting the
8 temperature signal from the level signal within the analog signal domain, etc.) of these
9 respective signals, prior to other possible signal processing operations (such as, for
10 example, formatting the media level signal, etc.).

11 In such an embodiment (not shown), for example, the sensor circuitry 312 can be
12 defined so as to not include the A-D converter 326 or the memory 332 (or its associated
13 program code 324 or lookup tables 340). Such an embodiment (not shown) of the
14 sensor circuitry 312 can include, for example: predominantly analog, digital, and/or
15 hybrid circuitry; a state machine; an application-specific integrated circuit (ASIC); etc.
16 Other embodiments (not shown) of the sensor circuitry 312 can also be used.

17 Fig. 5 is a block diagram depicting a sensor circuitry 412 in accordance with yet
18 another embodiment of the present invention. The sensor circuitry 412 includes a signal
19 processor 422. The signal processor 422 is generally configured to process and
20 compare signals corresponding to detected (i.e., sensed) level and temperature signals
21 coupled to the signal processor 422. The signal processor 422 can include any suitable
22 electronic circuitry as required to perform the various normal operations associated
23 therewith and as described in detail hereafter.

24 The sensor circuitry 412 also includes a pulse control 428 coupled in controlling
25 relationship with the signal processor 422. The pulse control 428 is generally configured
26 to control (i.e., coordinate) various normal operations of the sensor circuitry 412. The
27 pulse control 428 can include, for example: digital, analog, or hybrid circuitry; timing
28 electronics; dedicated-purpose integrated circuits; etc. In general, the pulse control 428
29 can be defined by any electronic circuitry suitable for controlling the sensor circuitry 412.

30 The sensor circuitry 412 also includes first current source 430 and a second
31 current source 431. The first and second current sources 430 and 431 are configured to
32 provide substantially equal pulses of electrical current in response to a trigger signal
33 (i.e., first signal) issued by the pulse control 428. The first current source 430 and the
34 second current source 431 can include any suitable electrical or electronic circuitry as
35 required, respectively.

1 As depicted in Fig. 5, a thermistor level sensor (hereafter, TLS) 414 is electrically
2 coupled to the first current source 430. The TLS 414 is generally configured to provide a
3 level signal (i.e., voltage signal) corresponding to a level of an imaging media (see the
4 imaging media 108 of Fig. 1) in contact with a lengthwise portion of the TLS 414 in
5 response to the pulse of electrical current provided by the first current source 430. Thus,
6 the TLS 414 can be generally defined by any suitable thermal level sensor of the present
7 invention.

8 The sensor circuitry 412 also includes an ambient temperature sensor (hereafter,
9 ATS) 434. The ATS 434 is electrically coupled to the second current source 431. The
10 ATS 434 is configured to provide a temperature (or reference) signal generally
11 corresponding to the ambient temperature about the ATS 434. Typically, the ATS 434 is
12 supported in relatively near, spaced adjacency to the TLS 414 such that the ambient
13 temperature exposed to the ATS 434 is substantially common to the two during periods
14 of non-energized operation. Typically, the ATS 434 and the TLS 414 are selected such
15 that they have a common temperature coefficient. In one embodiment, the ATS 434 and
16 the TLS 414 are substantially equivalent entities. Other embodiments can also be used.

17 It is to be noted that the first current source 430, the second current source 431,
18 the TLS 414 and the ATS 434 are mutually electrically coupled such that a bridge circuit
19 436 is defined. The signal processor 422 is electrically coupled to the bridge circuit 436
20 at nodes "A" and "B", respectively. In this way, the signal processor 422 is coupled to
21 the bridge circuit 436 so as to detect the difference signal, or voltage, representative of
22 the difference between the level signal provided by the TLS 414 and the temperature
23 signal provide by the ATS 434.

24 Typical operation of the sensor circuitry 412 is as follows: to begin, it is assumed
25 that the TLS 414 is supported such that a level of an imaging media is in contact with a
26 lengthwise portion of the TLS 414 (see, for example, the TLS 114 in contact with the
27 imaging media 108 of Fig. 1).

28 The pulse control 428 then receives a signal requesting a media level signal
29 corresponding to the level of the imaging media (not shown) in contact with the TLS 414.
30 In response the, the pulse control 428 issues a first signal to the first and second current
31 sources 430 and 431 to provide a predefined pulse of electrical current to the TLS 414
32 and the ATS 434, respectively.

33 In response to the respectively applied pulses of electrical current, the TLS 414
34 and the ATS 434 each begin to self-heat. As the ATS 434 is assumed to be supported
35 in the ambient environment (i.e., air), and that the TLS 414 is at least partially contacted

1 with the imaging media (not shown), the ATS 434 is generally warming toward a higher
2 steady-state temperature than that of the TLS 414 (by virtue of thermal energy loss to
3 the contacting imaging media). In accordance with the thermal coefficients of each, a
4 greater level of imaging media in contact with the TLS 414 generally results in a greater
5 difference between the signal levels provided by the TLS 414 and the ATS 434,
6 respectively. To clarify, the greater the difference signal between the nodes A' and B',
7 the generally greater is the level of imaging media in contact with the TLS 414.

8 At some predetermined time after the issuance of the first signal - during a later
9 portion of the applied electrical pulses - the pulse control 428 issues a second signal to
10 the signal processor 422. In response, the signal processor 422 samples the difference
11 signal value (i.e., voltage) present between nodes A' and B' of the bridge circuit 436. In
12 accordance with the sampled signal value, the signal processor 422 provides a media
13 level signal to the requestor generally corresponding to the level (i.e., quantity) of media
14 detected by the TLS 414.

15 Thereafter, the pulse control 428 signals the first current source 430 and the
16 second current source 431 to end the application of electrical current to the TLS 414 and
17 ATS 434, respectively, thus ending the presently applied electrical pulses. In response,
18 the ATS 434 and the TLS 414 begin to cool back toward the ambient temperature. A
19 single operation, or iteration, of the sensor circuitry 412 is considered complete.

20 The sensor circuitry 412, in cooperation with the TLS 414, provides a media level
21 signal (or message) to a requesting entity (such as an imaging apparatus controller, or
22 user computer) corresponding to the quantity of imaging media presently within the
23 sensed reservoir or cartridge. Furthermore, the sensor circuitry 412 is generally
24 configured to do so by substantially direct detection of the difference signal (or voltage)
25 provided by the bridge circuit 436.

26 Fig. 6 is a front elevation view depicting a thermistor level sensor 500 in
27 accordance with still another embodiment of the present invention. The thermistor level
28 sensor (hereafter, TLS) 500 includes a substrate 502. The substrate 502 can be defined
29 by any suitable substantially non-electrically conductive material, which also exhibits a
30 relatively low thermal mass. Non-limiting examples of such a substrate 502 material
31 include glass, plastic, low-thermal-mass ceramic, etc. Other materials can also be used.
32 The substrate 502 generally defines a strip of material of relatively slight thickness.

33 The TLS 500 also includes a thermistor material 504. The thermistor material
34 504 is supported by the substrate 502. The thermistor material 504 can be generally
35 defined by any suitable such material which includes a usable temperature (i.e.,

1 electrical resistance-to-temperature) coefficient. Generally, the thermistor material 504
2 is selected to define a positive or negative temperature coefficient. The thermistor
3 material 504 can include, for example, barium titanate. Other thermistor materials 504
4 can also be used. As depicted in Fig. 6, the thermistor material 504 substantially defines
5 a strip of material including a lengthwise dimension or portion "L1" and a generally
6 constant cross-sectional area "A1".

7 The TLS 500 further includes a pair of lead wires 506. The lead wires 506 can be
8 formed from any suitable electrically conductive material such as, for example, copper,
9 silver, gold, etc. Other materials can also be used to form the lead wires 506. Each of
10 the lead wires 506 is electrically coupled to an opposite end of the thermistor material
11 504. In this way, the lead wires 506 permit electrically coupling the electrical resistance
12 provided by the thermistor material 504 to an outside entity (such as, for example, the
13 sensor circuitry 112 of Fig. 1).

14 Typical operation of the TLS 500 is as follows: the TLS 500 is supported such
15 that the lengthwise portion L1 of the thermistor material 504 is in contact with some level
16 (quantity) of imaging media (not shown; see the imaging media 108 of Fig. 1). The TLS
17 500 is then electrically energized by an external source (not shown; see the sensor
18 circuitry 112 of Fig. 1) coupled to the TLS 500 by way of the lead wires 506, typically in
19 the form of a pulse of substantially constant-magnitude electrical current.

20 In response to the electrical energization, the thermistor material 504 begins to
21 self-heat (i.e., generate heat) towards a steady-state temperature in excess of the
22 ambient temperature thereabout. A portion of the heat generated by the thermistor
23 material 504 is thermally coupled (i.e., transferred) to the imaging media (not shown) in
24 contact with the lengthwise portion L1 of the thermistor material 504.

25 After some period of time the TLS 500 reaches a steady-state temperature. This
26 steady-state temperature is substantially determined by the ambient temperature of the
27 TLS 500 and the level of imaging media (not shown) in contact therewith. Due to the
28 temperature coefficient of the thermistor material 504, the TLS 500 provides an electrical
29 resistance corresponding to the steady-state temperature now present.

30 The electrical resistance provided by the TLS 500 – now substantially at
31 steady-state temperature – is present as a voltage (i.e., level signal) between the two
32 lead wires 506 by virtue of the applied pulse of electrical current. This level signal is
33 then sampled (detected) by an exterior entity (not shown; see the sensor circuitry 112 of
34 Fig. 1) and a suitable media level signal is derived therefrom representative of the level
35 of the imaging media (not shown) in contact with the TLS 500. At this time, the external

1 source typically de-energizes the TLS 500, permitting it to cool back toward ambient
2 temperature. A single use of the TLS 500 is now generally considered complete.

3 The media level signal derivation process can include, for example, a comparison
4 of the level signal with an ambient temperature signal (i.e., a difference signal), the
5 cross-referencing of lookup tables in computer-accessible memory, direct conversion by
6 way of a state-machine, etc., in accordance with the present invention and substantially
7 as described above in regard to the sensor circuitry 112 of Fig. 1, the sensor circuitry
8 312 of Fig. 3, or the sensor circuitry 412 of Fig. 5.

9 It is important to note that the TLS 500 of Fig. 6 includes a thermistor material
10 504 defining a substantially constant cross-sectional area A1 along the lengthwise
11 dimension L1 thereof. As a result, the TLS 500 exhibits generally the same sensitivity or
12 level signal resolution at all levels of an imaging media (not shown) in contact therewith.
13 However, it is sometimes desirable to increase the signal resolution at certain areas
14 within the level measurement range, relative to that of other such areas. Typically, the
15 area of greatest level measurement interest (i.e., concern) occurs when the imaging
16 media in contact with a thermistor level sensor of the present invention is approaching or
17 within a generally low level. Devices in accordance with the present inventions are
18 described hereafter that address this level signal resolution issue.

19 Fig. 6A is a front elevation view depicting a thermistor level sensor (hereafter,
20 TLS) 530 in accordance with another embodiment of the present invention. The TLS
21 530 includes a substrate 532 and a pair of lead wires 536 that are defined, configured
22 and cooperative substantially as described above in regard to the substrate 502 and the
23 pair of lead wires 506, respectively, of the TLS 500 of Fig. 6.

24 Also the TLS 530 includes a thermistor material 534. The thermistor material 534
25 is supported by the substrate 532, and can be defined by any suitable such thermistor
26 material such as, for example, barium titanate. Other suitable thermistor materials can
27 also be used. The thermistor material 534 defines a generally upper lengthwise portion
28 "L2" including a generally constant cross-sectional area "A2". Furthermore, the
29 thermistor material 534 also defines a generally lower lengthwise portion "L3" including a
30 generally constant cross-sectional area "A3". It is to be noted that the cross-sectional
31 area A3 is generally less than the cross-sectional area A2.

32 In this way, the TLS 530 provides a level signal that exhibits increased signal
33 resolution corresponding to a measured level of imaging media (not shown) in contact
34 with the lower lengthwise portion L3, relative to the signal resolution corresponding to
35 the upper lengthwise portion L2. That is, the resolution of the level signal in units of, for

1 example, volts-per-centimeter of measured imaging media is greater for the lower
2 lengthwise portion L3 than for that of the upper lengthwise portion L2 of the thermistor
3 material 534. Thus, a greater sensitivity to lower levels of imaging media (not shown;
4 see the imaging media 108 of Fig. 1) is provided by the TLS 530 relative to that of the
5 TLS 500 of Fig. 6. The increased signal resolution notwithstanding, typical operation of
6 the TLS 530 is substantially the same as that described above in regard to the TLS 500
7 of Fig. 6.

8 Fig. 6B is a front elevation view depicting a thermistor level sensor (hereafter,
9 TLS) 560 in accordance with yet another embodiment of the present invention. The TLS
10 560 includes a substrate 562 and a pair of lead wires 566 that are substantially defined,
11 configured and cooperative as described above in regard to the substrate 502 and the
12 pair of lead wires 506, respectively, of the TLS 500 of Fig. 6.

13 The TLS 560 also includes a thermistor material 564. The thermistor material
14 564 can be formed from any suitable thermistor material such as, for example, barium
15 titanate. Other suitable thermistor materials can also be used. The thermistor material
16 564 defines a generally upper lengthwise portion "L4" including a substantially constant
17 cross-sectional area "A4". The thermistor material also defines a generally lower
18 lengthwise portion "L5" including a lengthwise varying cross-sectional area "A5". As
19 depicted in Fig. 6B, the cross-sectional area A5 of the lower lengthwise portion L5 of the
20 thermistor material 564 is configured such that a substantially linear taper away from the
21 upper portion L4 is defined. Other embodiments of the thermistor material 564 (not
22 shown) defining other lower portions L5 including correspondingly varying cross-
23 sectional areas A5 (i.e., overall geometries) can also be used.

24 In any case, the TLS 560 provides a level signal that exhibits a generally constant
25 signal resolution (i.e., volts-per-centimeter of contacting imaging media) over the upper
26 portion L4 while exhibiting a substantially increasing signal resolution within the lower
27 portion L5, as imaging media (not shown) in contact with the TLS 560 is decreased.
28 Thus, the TLS 560 exhibits increased sensitivity for imaging media (not shown) in
29 contact with the lower lengthwise portion L5 of the thermistor material 564. Aside from
30 the increased signal resolution, the typical operation of the TLS 560 is substantially the
31 same as that described above in regard to the TLS 500 of Fig. 6.

32 Fig. 6C is a front elevation view depicting a thermistor level sensor (hereafter,
33 TLS) 580 in accordance with yet another embodiment of the present invention. The TLS
34 580 includes a substrate 582 and a pair of lead wires 586 that are substantially defined,

1 configured and cooperative as described above in regard to the substrate 502 and the
2 pair of lead wires 506, respectively, of the TLS 500 of Fig. 6.

3 The TLS 580 also includes a thermistor material 584. The thermistor material
4 584 can be formed from any suitable thermistor material such as, for example, barium
5 titanate. Other suitable thermistor materials can also be used. The thermistor material
6 584 defines a generally upper lengthwise portion "L4' " including a substantially constant
7 cross-sectional area "A4' ". The thermistor material 584 also defines a generally lower
8 lengthwise portion "L5' " including a substantially constant cross-sectional area "A5' ".

9 As depicted in Fig. 6C, the lower lengthwise portion L5' extends generally
10 perpendicularly away from the upper lengthwise portion L4', such that the thermistor
11 material 584 defines a substantially L-shaped configuration supported on the substrate
12 582. In this way, the TLS 580 provides a level signal that exhibits a first signal resolution
13 (i.e., volts-per-centimeter of contacting imaging media) over the upper portion L4', while
14 exhibiting a substantially increased second signal resolution within the lower portion L5',
15 as imaging media (not shown) in contact with the TLS 580 is decreased. Thus, the TLS
16 580 exhibits increased sensitivity for imaging media (not shown) in contact with the lower
17 lengthwise portion L5' of the thermistor material 584. Aside from the increased signal
18 resolution, the typical operation of the TLS 580 is substantially the same as that
19 described above in regard to the TLS 500 of Fig. 6.

20 Fig. 7 is a side elevation schematic view depicting a thermistor level sensor
21 (hereafter, TLS) 600 in accordance with still another embodiment of the present
22 invention. The TLS 600 includes a plurality of discrete thermistors 602. Each of the
23 thermistors 602 can be defined by any suitable thermistor device usable in accordance
24 with the present invention.

25 In one embodiment, the thermistors 602 have substantially equal temperature
26 coefficients. In another embodiment, one or more of the generally lower thermistors 602
27 (exemplified as thermistor 603 in Fig. 7) has a temperature coefficient that is
28 substantially different from that of the other thermistors 602 of the TLS 600, such that an
29 increased signal resolution is provided during detection (i.e., measurement) of relatively
30 low levels of imaging media (not shown). One of skill in the electronic instrumentation
31 arts is aware of a number of suitable such thermistors 602 and further elaboration is not
32 required for purposes of understanding the present invention.

33 As depicted in Fig. 7, the thermistors 602 are mutually electrically coupled so as
34 to define a series circuit or linear array 604 including a lengthwise portion "L6".
35 Furthermore, the TLS 600 includes a pair of lead wires 606 that are respectively

1 electrically coupled to substantially end-most thermistors 602 of the array 604. The lead
2 wires 606 provided for electrically coupling the TLS 600 to an external circuit and/or
3 energy source (not shown; see the sensor circuit 112 of Fig. 1) during typical use
4 (described in detail hereafter).

5 Typical operation of the TLS 600 is generally as follows: the TLS 600 is
6 electrically coupled to a suitable external sensor circuitry (e.g., the sensor circuitry 112 of
7 Fig. 1) by way of the lead wires 606 and the TLS 600 is supported so that the lengthwise
8 portion L6 of the array 604 is in contact with an imaging media (not shown) to be
9 measured.

10 The external sensor circuit (not shown) then energizes the TLS 600 with a
11 suitable pulse of electrical current. In response, each of the thermistors 602 begins to
12 self-heat. Those thermistors 602 that are in contact (or partial contact) with the imaging
13 media transfer a portion of their heat energy thereto and, as a result, tend to remain
14 cooler than those thermistors 602 that are in contact with the ambient media (i.e., air).
15 The TLS 600 approaches an overall-steady state condition and provides a level signal
16 (voltage) corresponding to the level of imaging media (e.g., imaging media 108 of Fig. 1)
17 in contact with the lengthwise portion L6 of the TLS 600.

18 Thereafter, the external sensor circuitry (not shown) samples the level signal
19 voltage for purposes of providing a media level signal in accordance with the present
20 invention. The external sensor circuitry then de-energizes the TLS 600, effectively
21 halting the applied pulse of electrical current. The thermistors 602 of the TLS 600
22 generally begin to cool. A single operation of the TLS 600 is thus considered complete.

23 Fig. 8 is a side elevation view depicting a thermistor level sensor (hereafter, TLS)
24 700 in accordance with another embodiment of the present invention. The TLS 700
25 includes a mandrel 702. As depicted in Fig. 8, the mandrel 702 generally defines a
26 cylindrical rod. Other geometries of mandrel 702 can also be used. The mandrel 702
27 can be formed from any suitable, electrically non-conductive material of relatively low
28 thermal mass. Non-limiting examples of such a material include capton, plastic, etc.
29 Other suitable materials can also be used.

30 The TLS 700 also includes a thermistor wire 704. The thermistor wire 704 can be
31 formed from any suitable thermistor material that includes a generally suitable
32 temperature coefficient (i.e., electrical resistance-to-temperature correlation). In one
33 embodiment, the thermistor wire 704 is formed from tungsten. Other thermistor
34 materials can also be used. While tungsten exhibits a positive temperature coefficient,
35 materials of positive or negative temperature coefficients can be used. The thermistor

1 wire 704 is generally wound about (i.e., supported by) the mandrel 702 such that a helix
2 710 is defined including a lengthwise portion (or aspect) "L7".

3 Typical operation of the TLS 700 is as follows: the TLS 700 is supported so that a
4 level of an imaging media (not shown) is in contact with the lengthwise portion L7 of the
5 TLS 700. Then, an electrical current is applied to the thermistor wire 704 of the TLS 700
6 by an external sensor circuitry (not shown), resulting in a self-heating of the thermistor
7 wire 704. A portion of the heat energy thus generated is transferred to the imaging
8 media and a steady-state temperature condition is eventually achieved.

9 A voltage level signal is present across the TLS 700 corresponding to the level of
10 imaging media in contact therewith. This level signal is sensed (sampled) by the
11 external sensor circuitry and used or processed to provide a media level signal in
12 accordance with the level of the imagined media sensed by (in contact with) the
13 lengthwise portion L7 of the TLS 700. The applied pulse of electrical current is then
14 ended, and the TLS 700 cools toward ambient temperature. A single, general operation
15 of the TLS 700 is now considered complete.

16 Fig. 8A is a side elevation view depicting a thermistor level sensor (hereafter,
17 TLS) 750 in accordance with another embodiment of the present invention. The TLS
18 750 includes a mandrel 752. The mandrel 752 is defined, configured and cooperative
19 substantially as described above in regard to the mandrel 702 of the TLS 700 of Fig. 8.

20 The TLS 750 also includes a thermistor wire 754. The thermistor wire 754 can be
21 formed from any suitable thermistor material such as, for example, tungsten. Other
22 thermistor materials can also be used. The thermistor wire 754 is generally wound
23 about and supported by the mandrel 752 such that a helix 760 is defined. The helix 760
24 includes a generally upper lengthwise portion "L8" and a generally lower lengthwise
25 portion "L9". As depicted in Fig. 8A, the lower portion L9 of the helix 760 includes a
26 substantially different pitch (i.e., turns-per-centimeter length) about the mandrel 752,
27 than that of the upper portion L8.

28 In this way, the TLS 750 provides an increased level signal resolution
29 corresponding to an imaging media (not shown) in contact with the lower portion L9,
30 relative to the signal resolution for that imaging media in contact with the upper portion
31 L8. Thus, the TLS 750 provides increased sensitivity when measuring relatively low
32 levels of imaging media. The increased signal resolution notwithstanding, typical
33 operation of the TLS 750 is substantially the same as that described above in regard to
34 the TLS 700 of Fig. 8.

1 Fig. 9 is a front elevation view depicting a thermistor level sensor (hereafter, TLS)
2 800 in accordance with still another embodiment of the present invention. The TLS 800
3 includes a substrate 802. The substrate 802 can be formed from any suitable electrically
4 non-conductive material that also exhibits relatively low thermal mass. Non-limiting
5 examples include plastic, glass, some ceramics, etc. Other materials can also be used.

6 The TLS 800 also includes a thermal radiator 804. The thermal radiator 804 is
7 supported by the substrate 802 and defines a lengthwise portion "L10". As depicted in
8 Fig. 9, the lengthwise portion L10 includes a lengthwise varying cross-sectional area
9 "A10". In this way, the thermal radiator 804 defines a generally triangular shape
10 supported on the substrate 802. Other geometries (not shown) of thermal radiator can
11 also be used. The thermal radiator 804 can be formed from any suitable substantially
12 heat conductive material such as, for example, copper, aluminum, etc. Other materials
13 can also be used to form the thermal radiator 804.

14 The TLS 800 further includes a thermistor 810. The thermistor 810 is generally
15 supported by the substrate 802 and is thermally coupled to the thermal radiator 804 at a
16 generally upper end thereof. The thermistor 810 can be defined by any suitable
17 thermistor in accordance with the present invention. The thermistor 810 includes a pair
18 of lead wires 816 that are configured to permit electrically coupling the thermistor 810 to
19 a suitable external sensor circuitry (not shown; see the sensor circuitry 112 of Fig. 1).

20 Typical operation of the TLS 800 is as follows: the TLS 800 is assumed to be
21 coupled to suitable sensor circuitry of the present invention, such as, for example, the
22 sensor circuitry 112 of Fig. 1. The TLS 800 is also assumed to be supported such that a
23 level of imaging media (not shown; see imaging media 108 of Fig. 1) is in contact with
24 the lengthwise portion L10 of the TLS 800.

25 Next, the sensor circuitry (not shown) applies a pulse of electrical current to the
26 TLS 800 by way of the lead wires 816. In response, the thermistor 810 begins to
27 self-heat. A substantial portion of the heat energy generated by the thermistor 810 is
28 thermally conducted to the thermal radiator 804. In turn, the thermal radiator 804
29 transfers some portion of the thermal energy received from the thermistor 810 to the
30 imaging media (not shown) in contact therewith. Generally, the greater the level of
31 imaging media in contact with the lengthwise portion L10 of the thermal radiator 804, the
32 cooler the thermal radiator 804 will be once a steady-state condition is reached.

33 At some time after the onset of the applied pulse of electrical current, the external
34 sensor circuitry (not shown) samples the voltage (level signal) present between the lead
35 wires 816. This sampling is assumed to be performed at or before a substantially

1 steady-state thermal condition of the TLS 800 is realized. The level signal present
2 between the lead wires 816 corresponds to the level of imaging media in contact with the
3 lengthwise portion L10 of the thermal radiator 804. The sensor circuitry (not shown)
4 then provides a media level signal in accordance with the level signal, and generally
5 thereafter halts the applied pulse of electrical current to the TLS 800, which responds by
6 cooling back toward ambient temperature. A single operation of the TLS 800 is now
7 considered complete.

8 As described above, the thermal radiator 804 of the TLS 800 is generally
9 triangular in shape, such that the generally lower portion of the thermal radiator 804 is
10 wider than the generally upper portion. In this way, the general bulk of the thermal
11 energy is transferred to the imaging media (not shown) in contact with the lower (i.e.,
12 flared) portion of the thermal radiator 804. The overall result is that the TLS 800 exhibits
13 increased signal resolution with respect to generally lower level of imaging media in
14 contact with the thermal radiator 804. As described above, other geometries of thermal
15 radiator 804 can be formed, resulting in varying signal resolutions corresponding to
16 different lengthwise areas of the thermal radiator 804.

17 Fig. 10 is a side elevation sectional view depicting a thermistor level sensor
18 (hereafter, TLS) 914 in accordance with another embodiment of the present invention.
19 The TLS 914 can include any suitable thermistor level sensor in accordance with the
20 present invention. In one embodiment (not shown), the TLS 914 includes the thermistor
21 level sensor 500 of Fig. 6. In another embodiment (not shown), the TLS 914 includes
22 the thermistor level sensor 600 of Fig. 7. Other embodiments (not shown) of TLS 914
23 including other thermistor level sensor can also be used.

24 In any case, the TLS 914 also includes a thermal window 915. The thermal
25 window 915 defines a lengthwise portion "L11" of the TLS 914. As depicted in Fig. 10,
26 the thermal window 915 is configured to thermally couple the TLS 914 with an imaging
27 media 908 supported within a reservoir 910. In this way, the TLS 914 is supported
28 substantially exterior to the inside of the reservoir 910. The thermal window 915 is
29 typically formed from any relatively thin, smooth, thermally conductive material. Non-
30 limiting examples of such thermal window 915 material include plastic, capton, copper,
31 aluminum, etc. Other materials can also be used.

32 The TLS 914 also includes a pair of lead wires 916 configured to electrically
33 couple the TLS 914 with a suitable external sensor circuitry (not shown; see the sensor
34 circuitry 112 of Fig. 1).

1 Typical operation of the TLS 914 is as follows: a pulse of electrical current is
2 applied to the TLS 914 by way of a sensor circuitry (not shown) suitably coupled to the
3 lead wires 916. In response, the TLS 914 begins to self-heat, with a portion of the
4 correspondingly generated thermal energy being transferred to the imaging media 908
5 by way of contact with the thermal window 915.

6 The TLS 914 eventually reaches a thermal steady-state condition at a
7 temperature generally higher than ambient, and in accordance with the level "LM" of
8 imaging media 908 in contact with the lengthwise portion L11 of the TLS 914. At this
9 point, a level signal (voltage) corresponding to the level LM of the imaging media 908 in
10 contact with the thermal window 915. The sensor circuit (not shown) then samples this
11 level signal for purposes (typically) of providing a media level signal.

12 The sensor circuitry (not shown) then halts the pulse of electrical current to the
13 TLS 914. The TLS 914 responds by cooling generally toward ambient temperature. A
14 single operation of the TLS 914 is now complete.

15 As described above, the thermal window 915 provides for thermal communication
16 between the TLS 914 and the imaging media 908 whose level LM is to be measured.
17 Thus, the thermal window 915 provides for a smooth form of shielding or mechanical
18 buffering between the TLS 914 and the imaging media 908. In this way, the imaging
19 media 908 tends to readily slough off of the thermal window 915 as the imaging media
20 908 is consumed (i.e., used in by an associated imagined apparatus, not shown) and
21 does not generally accumulate, or clump, on the thermal window 915, thus reducing the
22 likelihood of false measurements (i.e., erroneous level signals) provided by the TLS 914
23 during operation.

24 Fig. 11 is a side elevation sectional view depicting a thermistor level sensor
25 (hereafter, TLS) 950 in accordance with yet another embodiment of the present
26 invention. The TLS 950 includes a thermal conductor 954. The thermal conductor 954
27 can be formed from any suitable thermally conductive material such as, for example,
28 copper aluminum, etc. Other materials can also be used. The thermal conductor 954
29 can further be formed in any of a number of suitable geometries. As depicted in Fig. 11,
30 the thermal conductor 954 generally defines a cylindrical rod. In any case, the thermal
31 conductor defines a lengthwise portion "L12" of the TLS 950.

32 The TLS 950 also includes a thermistor 964. The thermistor 964 is thermally
33 coupled to a generally lower end "LE" of the thermal conductor 954. The thermistor can
34 be defined by any suitable thermistor. One of skill in the electronic arts can appreciate
35 that a number of such thermistors 964 can be used and that further elaboration is not

1 required for purposes herein. The thermistor 964 includes a pair of temperature sense
2 leads 966 configured to electrically couple the thermistor 964 to a suitable sensor
3 circuitry (not shown; see the sensor circuitry 112 of Fig. 1).

4 The TLS 950 also includes an electric heater 956. The electric heater 956 is
5 thermally coupled to a generally upper end "UE" of the thermal conductor 954. The
6 electric heater 956 can be defined by any suitable electric heating element consistent
7 with the present invention. In one embodiment, the electric heater 956 is substantially
8 equivalent to the thermistor 964. Other electric heaters 956 can also be used. The
9 electric heater 956 includes a pair of heater leads 968 configured to electrically couple
10 the electric heater 956 to a suitable source of electrical energy such as, for example, the
11 sensor circuitry 112 of Fig. 1, or the current source 330 of Fig. 3.

12 As depicted in Fig. 11, the thermal conductor 954 is generally supported within a
13 reservoir 960 containing (i.e., supporting) an imaging media 958. A level "LM'" of the
14 imaging media 958 is in contact with the lengthwise portion L12 of the TLS 950.

15 Typical operation of the TLS 950 is as follows: a pulse of electrical current is
16 applied to the electric heater 956 by an external source (not shown) by way of the heater
17 leads 968. In response, the electric heater 956 begins to generate thermal energy that
18 is transferred in substantial portion to the thermal conductor 954. In turn, the thermal
19 conductor 954 conducts this thermal energy generally away from the upper end UE
20 toward the thermistor 964 at the lower end LE.

21 As the thermal conductor 954 conducts the thermal energy, a portion is thermally
22 transferred to the imaging media 958 that is in contact with the thermal conductor 954.
23 As a result, the thermal conductor 954 generally warms toward a steady-state
24 temperature in accordance with the level LM' of imaging media 958 in contact therewith.
25 Generally speaking, the greater is the level LM' of imaging media 958, the relatively
26 lower will be the eventual steady-state temperature of the thermal conductor 954. The
27 thermistor 964 provides an electrical resistance (i.e., level signal) corresponding to the
28 temperature of the lower end of the thermal conductor 954.

29 At some time at or before a steady-state thermal condition of the thermal
30 conductor 954, a sensor circuitry (not shown) coupled to the thermistor 964 by way of
31 the temperature sense leads 966 samples the electrical resistance (level signal) thereof.
32 The sensor circuit then typically derives a media level signal corresponding to the level
33 LM' of the imaging media 958 within the reservoir 960 from the sampled level signal. At
34 this time, the external source (not shown) is assumed to halt the pulse of electrical
35 current to the electric heater 956, and the TLS 950 as a whole is considered to cool

1 toward ambient temperature. A single operation of the TLS 950 is now considered
2 complete.

3 Thus, the TLS 950 provides for a level signal corresponding to – and thus a
4 general measurement of – the level LM' of the imaging media 958 within the reservoir
5 960.

6 Fig. 12 is a flowchart depicting a method 1000 in accordance with the present
7 invention. It is to be understood that while the method 1000 describes particular steps
8 and order of execution, other embodiments of the present invention respectively
9 describing other methods and order of execution can also be used. For clarity of
10 understanding, the method 1000 is described in the context of the imaging system 100
11 of Fig. 1. It is to be further understood that the method 1000 and/or its appropriate
12 variations can also be applied to level measurements other than imaging media (e.g.,
13 pharmaceuticals, industrial material processing, etc.).

14 In step 1002 (Fig. 12), the controller 104 (Fig. 1) issues a measurement signal
15 requesting that the sensor circuitry 112 provide a media level signal representing the
16 quantity of the imaging media 108 within the reservoir 110.

17 In step 1004 (Fig. 12), the sensor circuitry 112 (Fig. 1) responds by initiating a
18 pulse of substantially constant-magnitude electrical current to the thermistor level sensor
19 (TLS) 114.

20 In step 1006 (Fig. 12), the TLS 114 (Fig. 1) responds to the electrical current by
21 beginning to generate heat, warming the TLS 114 toward a substantially steady-state
22 temperature. The sensor circuitry 112 waits during a predetermined initial portion of the
23 applied pulse of electrical current.

24 In step 1008 (Fig. 12), TLS 114 (Fig. 1), at or before a steady-state thermal
25 condition, provides a level signal (voltage) corresponding to the level L of imaging media
26 108 in contact therewith.

27 In step 1010 (Fig. 12), the sensor circuitry 112 (Fig. 1) samples the level signal
28 (voltage) provided by the TLS 114 and derives a media level signal representing the
29 quantity of imaging media 108 within the reservoir 110 for communication to the
30 controller 104.

31 In step 1012 (Fig. 12), the sensor circuitry 112 (Fig. 1) ends (i.e., halts) the pulse
32 of electrical current being provided to the TLS 114. In response, the TLS 114 cools
33 substantially toward ambient temperature. A single operation (or iteration) of the method
34 1000 is generally considered complete.

1 While the various embodiments of the present invention described above are
2 generally presented within the context of sensing (i.e., detecting, or measuring) imaging
3 media as used with an imaging apparatus (for example, the imaging media 108 of the
4 imaging apparatus 102 of Fig. 1), it is to be understood that embodiments of the present
5 invention can also be used in a number of other suitable applications such as, for
6 example, measurement of material (media) levels in tanks or vats (e.g., chemicals,
7 powdered compounds, petroleum, pharmaceuticals, etc.), or the level of a flowing media
8 within an open or closed conduit (e.g., weirs, troughs, pipes, etc.).

9 In the case of a flowing material (i.e, media such as, for example, ink), a suitable
10 thermistor level sensor (e.g., TLS 114, 314, 414, etc.) can be energized using a
11 substantially constant electrical current – that is, the thermistor level sensor (not shown)
12 can be continuously electrically energized for an indefinite period of time. Thus, the use
13 of a pulse of electrical current (e.g., electrical pulse 202 of Fig. 2) would be optional in
14 such a circumstance. Other embodiments (not shown) of the present invention suitable
15 for use in other applications can also be used. In any case, each of the sensor circuits
16 of the present invention (e.g., sensor circuitry 112, 312, 412, etc.) is generally configured
17 to limit (or control) the electrical current being provided to an associated thermistor level
18 sensor (e.g., TLS 114, 314, 414, etc.) so as to substantially prevent heat related damage
19 to the imaging media being measured or detected.

20 While the above methods and apparatus have been described in language more
21 or less specific as to structural and methodical features, it is to be understood, however,
22 that they are not limited to the specific features shown and described, since the means
23 herein disclosed comprise preferred forms of putting the invention into effect. The
24 methods and apparatus are, therefore, claimed in any of their forms or modifications
25 within the proper scope of the appended claims appropriately interpreted in accordance
26 with the doctrine of equivalents.